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THE DIFFERENTIATION OF DIVERTICULITIS AND CARCINOMA OF THE LARGE BOWEL: A ROENTGENOLOGIC PROBLEM

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"In the Century and Oxford dictionaries, a diverticulum is described as a 'way-side shelter or lodging', with, from the context, the underlying meaning that they are houses of ill repute where trouble is apt to brew. In the large intestine, they live up to their bad reputation, and as a temporary lodging for bowel contents can give rise to endless trouble".

Boyd has considered Fraser's notation of "endless trouble" as referring to the development of diverticulitis, which was undoubtedly the meaning originally intended. However, another interpretation might be the 'trouble' which confronts the physician in the diagnosis and treatment of that condition. The difficulty arises largely in the differentiation of the moderately advanced form of diverticulitis from other diseases which it may closely mimic, the most prominent of which is carcinoma.

Differentiation between diverticulitis and carcinoma of the distal descending colon or sigmoid has been a major problem in 159 patients studied by the Departments of Surgery and of Radiology in the Royal Victoria Hospital, during the twelve-year period from January 1937 to March 1949. The relative frequency of the two lesions is disturbingly similar, 91 cases (57%) of the series having carcinoma and 66 (42%), diverticulitis. The concomitant occurrence of carcinoma and diverticulitis, 2 in 159, (1.3%), is in close agreement with figures reported elsewhere. (Grout; Rankin and Brown).

The similarity of the clinical history and physical findings in the two conditions places the major diagnostic responsibility upon the Radiologist, especially when the lesion is not visible on sigmoidoscopy.

Historical

Diverticula of the large bowel were first noted by Friend in 1730, but were not described as a disease entity until 1849 (Cruveilhier). In 1853, Virchow used the phrase "isolated, circumscribed adhesive peritonitis" to describe a case which was probably diverticulitis, but it was left to Graser and Fisher in 1898 to draw attention to the condition as an important clinical entity, and to describe the difficulty of differentiation from carcinoma (with the methods then available). The radiologic diagnosis of diverticulosis was brought into prominence by Case's work in 1915. Since that time, the radiologic literature has contained many excellent discussions of both diverticulosis and its inflammatory state (diverticulitis). The possible differential characteristics of carcinoma compared to diverticulitis, however, have not received as much attention, although a few excellent articles have appeared on that subject. (Schatzki; Golden).

Clinical Considerations

Unfortunately, in the great majority of cases, the clinical manifestations of carcinoma of the distal large bowel are equally applicable to diverticulitis, and are not sufficiently typical to enable the physician to render an unequivocal diagnosis. Similar age groups, with a male sex predominance in both, render these points of no value in differential diagnosis. Pain is a variable feature. Although constipation is common to both, diarrhoea is not infrequent, and some patients may insist that their bowel habits are normal. Willard and Bochus speak of a "diverticulitis syndrome", consisting of "gastric indigestion", flatulence, abdominal pain, and alternating constipation and diarrhoea. However, these symptoms are too common in carcinoma of the distal colon to be of much value in this differential diagnosis.

Melena is of considerable value in the differentiation of these two conditions, being frequent in carcinoma, but relatively uncommon

in diverticulitis. Its frequency in the latter condition has been variably reported as 25% (Oren), 18% (Judd and Pollock), 17% (Rankin and Brown), 10% (Jones), and 5% (Spriggs). Sosman states that it never occurs. Schatzki believes that if diverticulitis is suspected clinically, and melena is found, another source for the bleeding must be sought, or the probability of carcinoma strongly considered. Gross blood in the stools was observed in only one of our cases of diverticulitis. Considering the relative frequency with which melena occurs in carcinoma of the distal colon, we believe that the presence of bleeding should definitely favor that diagnosis.

Physical examination is equally disappointing. The presence of tenderness does not include carcinoma, nor does its absence exclude diverticulitis. A mass may be palpable in either, although perhaps more commonly in diverticulitis. The sigmoidoscope remains as the principal diagnostic implement in the armamentarium of the surgeon who is faced with this problem. It must be realized, however, that the most frequent site of diverticulitis of the colon is in the sigmoid, and any tumour which might cause difficulty in differential diagnosis may well be out of reach of the sigmoidoscope. Spasm and edema of the adjacent bowel wall will add to the inaccessibility. This is the rule rather than the exception in diverticulitis. A negative biopsy can never be regarded as conclusive evidence of the absence of malignancy. The responsibility for the differential diagnosis in such circumstances rests almost entirely with the radiologist. In view of the high operative mortality attendant upon one-stage resections of diverticulitis (Schatzki; Cattell; Laufman) which may have been mistaken for carcinoma, this responsibility is indeed a great one.

Correlation of Pathological Changes with Roentgenologic Signs of Diverticulitis

Pathologically, diverticulitis may vary from an early inflammatory reaction in one or two diverticula to a locally stenosing, densely fibrotic pericolitis or perisigmoiditis, often with an associated abscess.

Singleton and Hall have described three stages of development of the lesion, correlating the roentgenologic signs with the gross pathologic changes in each.

During the *first stage*, the involvement of the bowel wall by an acute inflammatory process induces spasm of the circular muscle, with the resultant jagged saw-tooth appearance of the lumen of the barium-filled colon, characteristic of early diverticulitis. Upon palpation under the fluoroscope, a well-localized associated area of tenderness will be found.

In the *second stage*, progression of the inflammatory process with beginning fibrotic reaction causes an increase in deformity. Narrowing of the lumen becomes more marked, but the spasm is not so apparent. Local tenderness persists. There will be no palpable mass, but some resistance may be noted.

The *third stage* is characterized by further progression of the pericolitis, with abscess formation. The bowel wall becomes tremendously thickened and fibrotic, with marked narrowing of the lumen. The defect is constant, local spasm is not possible, but associated spasm of the adjacent bowel is often detectable.

The changes in the earlier stages are sufficiently characteristic to cause little difficulty in radiologic interpretation, but in the later phases of stage II, and particularly in stage III, confusion between diverticulitis and carcinoma is most likely to arise.

Radiological Considerations

From the radiological viewpoint, the differential diagnosis between carcinoma and diverticulitis of the distal large bowel is based chiefly on three observations:

1. The presence or absence of diverticula.
2. The character of the mucosal pattern.
3. The length and contour of the lesion.

Diverticula: Considerable discussion has arisen in the past as to the relative significance of diverticula in the differentiation of carcinoma from diverticulitis. Many theories have been suggested to explain the development of diverticulosis, but most authors consider that elevation of intracolonic pressure, with widening of the hiati for the vessels perforating the muscle coat, is one of the principal factors. It is reasonable to expect that in the older patient, especially when degenerative changes may have been induced by age, obesity or repeated bouts of infection, diverticulosis will be increasingly common, and that any obstructive syndrome such as that caused by a carcinoma of the rectosigmoid or sigmoid colon may increase the frequency of diverticula. The presence of diverticula therefore may be considered as but a warning signal to the observer.

Since diverticulitis never occurs without the preliminary development of diverticulosis, the absence of demonstrable diverticula in the presence of a stenosing lesion of the low bowel is significant, and strongly indicative of carcinoma. In this connection, it is important to bear in mind that the ostia of many diverticula may be extremely narrowed by edema, so that it is difficult for barium to enter the sacs. Not infrequently diverticula are best seen at the post-evacuation examination, whereas they were not

visible at the time of filling. If diverticulitis is suspected clinically and diverticula are not observed during the examination of the colon by barium enema, it is wise to examine the patient periodically later in the day, or even after 24 hours, so that any diverticula present may be given a chance to fill during the disposal of the residue of the opaque enema. Some authors (Schatzki; Golden) have suggested that the cautious injection of air for double-contrast study may demonstrate diverticula where barium alone will fail. In our Department, the use of gaseous contrast media in the presence of possible inflammatory lesions of the bowel is not regarded favourably.

Mucosal Pattern: Apart from edema and infiltration with chronic inflammatory cells, the mucosa in diverticulitis undergoes no appreciable alteration. Fluoroscopic and film examination will therefore reveal a relatively normal uninterrupted mucosal surface, with perhaps some mild distortion by edema, although the contour of the lumen may be grossly altered by the spasm and fibrosis of the colonic wall. (Figs. 1 and 2). Carcinoma, on the other hand, characteristically destroys the mucosa, and an irregular outline of the interrupted mucous membrane will be observed. (Figs. 3 and 5).

Length and Contour: Probably the most important roentgenologic sign by which a differential diagnosis may be made is the length and the contour of the lesion. The involved area in diverticulitis is characteristically long, while that in carcinoma is generally much shorter. (Figs. 2 and 5). Similarly the typical overhanging edges of the cuff of uninvolved bowel above and below the irregular tubular lumen of the fungating carcinoma are in striking contrast to the typical lesion of diverticulitis, in which the narrowed segment of bowel gradually expands, with more or less serration, both proximally and distally until the normal lumen is reached. (Figs. 2, 4 and 5). It should be strongly emphasized that these findings are of the typical case, and that many variations will be met. The scirrhous carcinoma may show a conical configuration of the lumen above or below, sometimes similar to the distortion of diverticulitis with abscess. Not uncommonly, a carcinoma will produce a prominent overhanging shelf at the proximal end of the tumour while the distal end will slope off, causing a cone-shaped and ill-defined distal lumen. This is presumably caused by repeated peristaltic waves and was observed in a few of our cases. (Fig. 4). Although the bowel proximal and distal to a carcinoma usually appears normal, it may show evidence of increased irritability and spasm due to local ulceration with infection. Spasm is much more common in diverticulitis, but its presence should not influence one's opinion too greatly against a diagnosis of carcinoma.

In cases of complete obstruction to the enema, barium will outline the distal end of the lesion

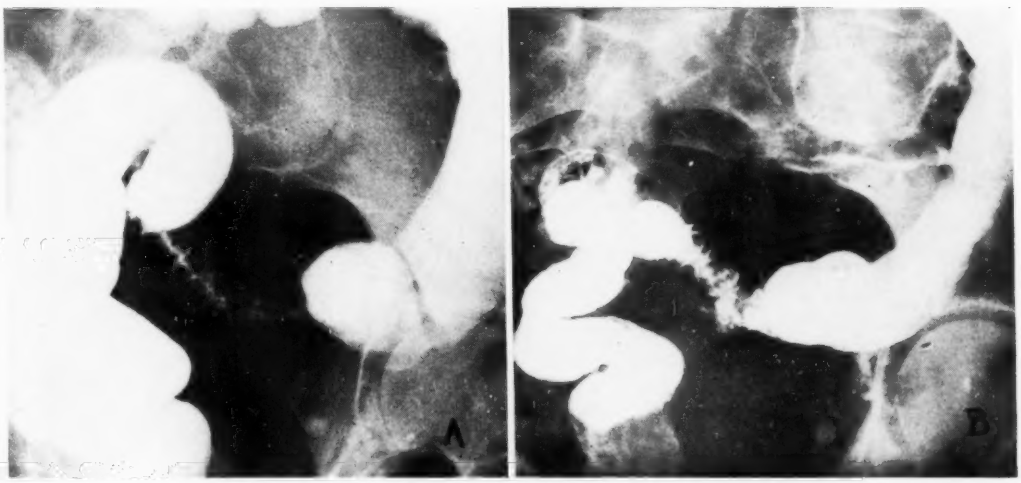

Fig. 1: A 52 year-old woman with a history of intermittent constipation, decreased calibre of the stool, and tenesmus for six months. Severe crampy lower abdominal pain had been present for three weeks. No melena. Physical examination was negative.

A. First examination: The normal mucosal pattern is preserved; diverticula are shown within and proximal to the involved segment. The sharply demarcated proximal and distal extremities are somewhat atypical.

B. Three weeks later, following colostomy. Considerable improvement has occurred in the local area of stenosis. The radiological impression of *diverticulitis* was confirmed by clinical follow-up.

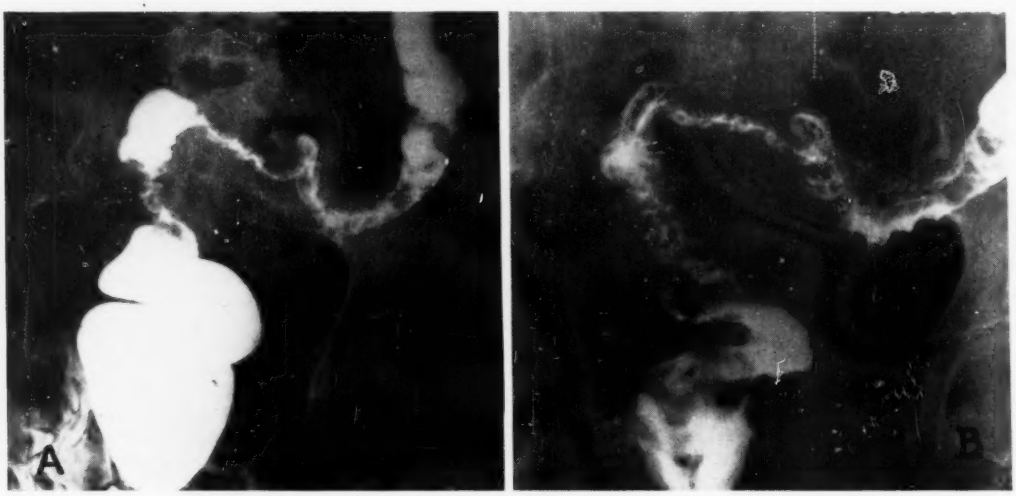

Fig. 2: A 45 year-old woman who gave a history of constipation for one year, increasing during the past month, and low abdominal pain for one month. No melena. A large firm, tender mass was palpable in the left lower quadrant.

A. Note the extensive involvement of the sigmoid, and the poorly-defined cone-shaped extremities of the barium column.

B. Post-evacuation film. The normal mucosal pattern is well demonstrated. Note the small diverticula. The radiological impression of ***diverticulitis*** was confirmed by clinical follow-up.

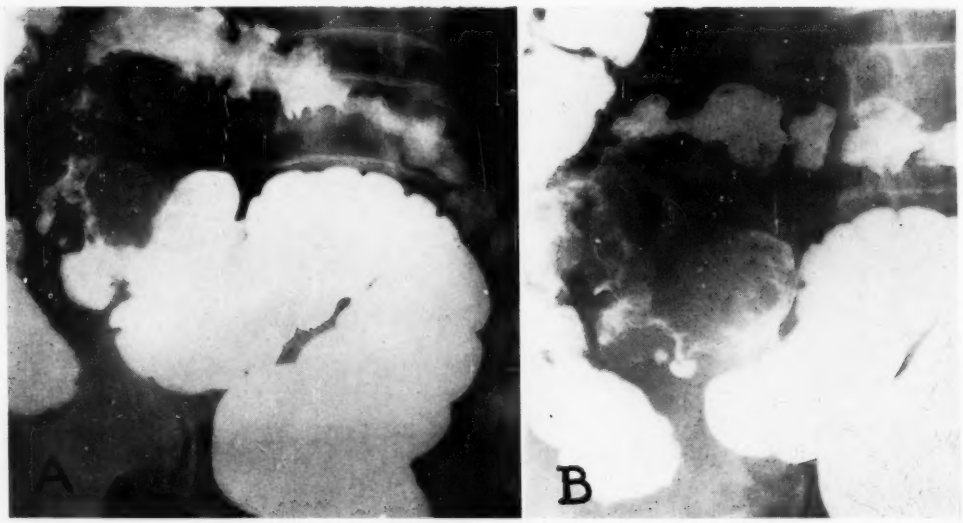

Fig. 3: A 59 year-old man who had noticed a sudden change in bowel habits 3 months previously, often with gross blood in the stool. He had lost 10 pounds in weight in the past 1½ months. Physical examination was negative.

A. Note the marked distortion of the mucosal pattern, and the multiple diverticula within and proximal to the lesion.

B. A large shelf is apparent at the distal end of the lesion. The radiological impression of ***carcinoma*** was confirmed at laparatomy.

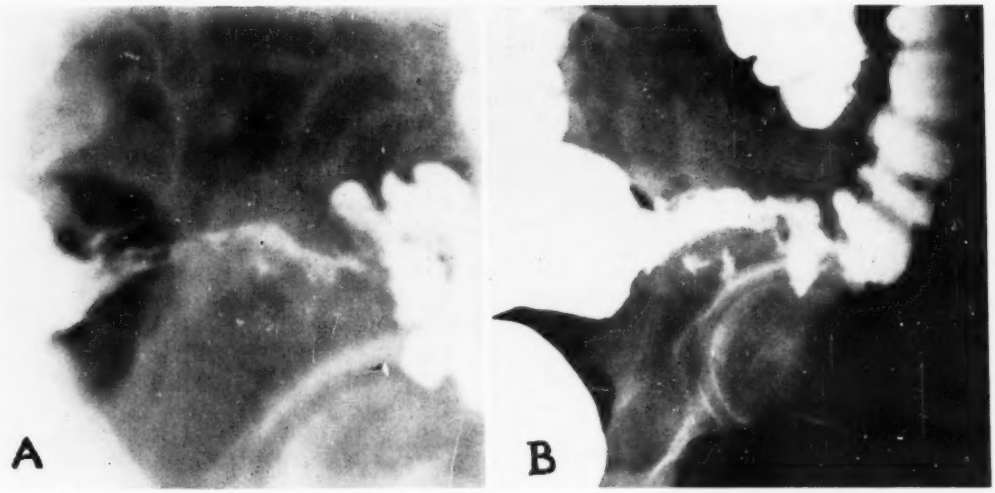

Fig. 4: A 45 year-old man with a history of intermittent bleeding per rectum for 12 years, "brownish-slime" in the stool for 4 months, and loss of 12 pounds in weight. Physical examination was negative.

A. A spot-detail roentgenogram demonstrates the limits of the lesion to good advantage. The mucosal pattern is not grossly deformed. Two small diverticula were identified within the lesion on the original film, but cannot be shown on the reproduction.

B. The lesion is fairly well demarcated, with a shelf at the proximal end and a cone-shaped distal end. The lumen is very irregular.
Radiological impression: ***probable diverticulitis; carcinoma cannot be excluded.***
Pathologist's report on the resected specimen was ***polypoid fungating carcinoma.***

Fig. 5: An elderly man on whom no history is available. The sharply-demarcated constricting lesion at the recto-sigmoid junction is well-demonstrated, with a prominent overhanging shelf and distortion of the mucosal pattern. Proximal to this lesion, the sigmoid presents a ragged saw-tooth appearance, associated with many diverticula.

The radiological impression of ***coexisting carcinoma and diverticulitis*** was confirmed at laparatomy.

only, and under such circumstances the difficulty of differential diagnosis is increased. However, in these cases, the presence of overhanging, sharply defined edges, above an adjacent bowel which balloons out well, should strongly arouse one's suspicion of carcinoma. In the great majority of instances, such cases will be treated conservatively, with caecostomy or colostomy. Subsequent barium enema examination, after the immediate crisis has passed, will tend to reveal the true nature of the lesion. In our laboratories, it has been the general observation that complete obstruction to the enema is not common in diverticulitis alone, occurring in only 7.5% of our series.

Concomitant diverticulitis and carcinoma of the colon in the same patient is uncommon. (Fig. 5). There is apparently no more cause and effect relationship between diverticulitis and carcinoma of the sigmoid than between diverticulitis of the sigmoid and carcinoma of the transverse colon, as was the situation in one of the two patients in whom the lesions coexisted. Grout reports 2 cases of diverticulitis in 91 cases of carcinoma (2.2%), and Rankin and Brown found the two coexisting in 4 out of 227 cases of diverticulitis (1.8%). In our series, (92 carcinoma and 67 diverticulitis), both conditions were concurrent in only 2 (1.3%). These percentages confirm our opinion, and that of most authorities, that no direct etiological relationship exists between the two.

TABLE I

Roentgenologic Diagnosis	*Number of Cases*	*Final Diagnosis*	*Number of Cases*
Diverticulis	56	Diverticulis	55
		Coexisting Carcinoma	1
Carcinoma	81	Carcinoma	77
		Diverticulis	4
Either—Diverticulitis or —Carcinoma	11	Carcinoma	8
		Diverticulitis	3
Coexisting Diverticulitis and Carcinoma	2	Coexisting	1
		Diverticulitis only	1
Radiologically considered negative	8	Carcinoma	6
		Diverticulitis	2
Syphilis or lymphosarcoma	1	Carcinoma	1
	159	90.6% Confirmation	159

TABLE II

Evaluation of Cases in which X-Ray Diagnosis not Confirmed

	Radiological Diagnosis		*Final Diagnosis*	*Number of Cases*	
A.	*Normal Colon*	8	Carcinoma	6	Fluoroscopic notes and interpreattion clear.
					Films not available on 4. In remaining 2, films demonstrate no abnormality.
					Significant dearth of spot detail films.
			Diverticulitis	2	Films not available on one. Films on the other show slight irregularity of sigmoid suggestive of early saw-tooth deformity.
					Spasm observed fluoroscopically.
B.	*Carcinoma*	4	Diverticulitis	4	1. Films not available.
					2. Complete obstruction with suggestion of overhanging edges. No diverticula. We concur in suspicion of carcinoma.
					3. Localized filling defect of sigmoid with overhanging edges and no diverticula. Radiologic Diagnosis well-founded.
					4. Films do not adequately demonstrate the lesion. *No spot detail films.* Multiple diverticula.
C.	*Diverticulitis*	1	Coexisting	1	Films not available.
D.	*Coexisting*	1	Diverticulitis *only*	1	Films reveal definite narrowing of a segment of sigmoid which would have to be regarded with marked suspicion. Mucosal pattern appears preserved.
E.	Syphilis or Lymphosarcoma	1	Carcinoma	1	Films not available.
		15		15	

Analysis of Cases

Of the 159 patients included in this survey, (examined between January 1937 and March 1949), 91 had carcinoma, 66 diverticulitis, and 2 both lesions. (Table I).

For this comparative analysis, the criteria for inclusion were:

(a) An organic lesion of the distal descending colon, sigmoid or recto-sigmoid junction;
(b) Adequate radiologic examination with contrast media; and
(c) Surgical or post-mortem confirmation, or a sufficiently long clinical follow-up to establish a relatively unequivocal diagnosis.

The patients in whom the diagnosis has been confirmed by long clinical follow-up were those in whom surgical intervention was not indicated or was delayed on the basis of the radiologic evidence.

Although the films on the majority of cases prior to 1943 had been discarded, the radiologist's notes and interpretation have been reviewed. In all others we have reviewed the fluoroscopic notes, films and interpretation, especially in all cases in which the roentgenologic opinion did not agree with the final diagnosis.

The roentgen diagnosis was in error in 15 cases of the 159, or 9.4% — Table II. The largest number of these (8) was considered to have no radiologic evidence of abnormality, save for a few diverticula in two patients. Six of these eight proved to have carcinoma, and two diverticulitis. Review of the films on several of these revealed a dearth of spot-detail studies. This emphasizes our belief that spot films, as well as fluoroscopy, with the patient in different degrees of rotation, are of major importance in the detection of lesions in this area.

Four of the seven remaining cases were diagnosed radiologically as carcinoma, but eventually proved to be diverticulitis. At laparatomy, two of these four were regarded as inoperable carcinoma, and a palliative colostomy performed without biopsy. Subsequent clinical course, however, has necessitated a change in diagnosis, since both patients are alive and well three years later without evidence of neoplastic disease. These two cases illustrate how difficult or impossible differentiation of the two conditions may be, even on direct visualization of the lesion in situ at laparatomy. Not uncommonly the pathologist will require his microscopic examination rather than venture an opinion on the gross specimen.

Upon review of the roentgenograms on the other two of these four patients, we are inclined to believe that the radiologic opinion of carcinoma was well-founded. In both, there was a rather short lesion with shelf-like overhanging extremities, an apparent distortion of the mucosal pattern, and no evidence of diverticula.

Two patients were found to have coexisting carcinoma and diverticulitis. In one of these, the carcinoma was in the transverse colon and the diverticulitis in the sigmoid, both lesions having been so diagnosed by x-ray. The other patient had diverticulitis of the sigmoid and carcinoma of the rectum. The barium enema was reported as failing to demonstrate any abnormality of the rectum. The films are no longer available for review.

In one case, barium enema revealed an annular constricting lesion of the sigmoid, considered as probably carcinoma, superimposed on a diverticulosis and diverticulitis. This patient was not operated upon. Subsequent examination revealed a definite improvement in the local area previously suspected of being carcinoma. He is alive and well five years later. Review of his films leads us to believe that the mucosal pattern in this suspected carcinomatous area was more or less preserved. However, if the films were put before us tomorrow, we probably would be inclined to render the same opinion.

The one case of carcinoma which was diagnosed as either syphilis or lymphosarcoma, presented a smooth narrowing of the sigmoid, four to five inches in length, perfectly regular in outline and without evidence of any diverticula. The lesion was described as not having the appearance of carcinoma. In this regard, other conditions have also given rise to confusion in differential diagnosis. Richard Cattell, in his discussion of a paper by Ross Golden on the same subject in 1934, referred to endometriosis of the sigmoid as offering some difficulty in differential diagnosis, especially when complete obstruction is present. To our knowledge, we heve not seen any cases of endometriosis of this segment of large bowel.

Both diverticulitis and carcinoma were included as major possibilities in the differential diagnosis of eleven of the 159 cases. Eight proved to be carcinoma, and three diverticulitis. It is interesting to note that two of the three with diverticulitis had complete obstruction to the flow of barium at the time of the enema. In the other nine, in all of which the lesion was satisfactorily outlined by barium, the difficulty in interpretation was caused by the presence of characteristic features of both lesions. One case which proved to be carcinoma had a long lesion, with multiple diverticula, but without demonstrable gross distortion of the mucosal pattern. In three of the cases with carcinoma, diverticulitis was mentioned as the major probability mainly on the presence of diverticula, even

though the lesions were highly suggestive of carcinoma. In another, the presence of tenderness was the only basis upon which diverticulutis was suggested as more probable.

Review of the films confirms the opinion that in the majority of instances, the lesions presented sufficiently atypical characteristics to warrant the inclusion of both in the differential diagnosis. In a few, however, we believe that too much stress was placed on one feature, when the bulk of the evidence pointed to one diagnosis. A more thorough fluoroscopic examination with associated spot-detail films in varying degrees of rotation would have helped materially in a few of the cases.

CONCLUSIONS

(1) In the absence of a positive biopsy by sigmoidoscopy, the differential diagnosis between diverticulitis and carcinoma of the distal descending colon and sigmoid is primarily a roentgenologic problem, due to the similarity and indefinite character of the clinical history and physical findings.

(2) The presence of local tenderness and a palpable mass are of doubtful differential value, but it is our impression that both are more common in diverticulitis. Spasm within or adjacent to the lesion is a more frequent observation in diverticulitis.

(3) The roentgenologic differential diagnosis should be based chiefly on three observations:

(a) The presence or absence of diverticula. Although diverticula may coexist, the absence of demonstrable diverticula strongly favours a diagnosis of carcinoma.

(b) The character of the mucosal pattern — preservation in diverticulitis, destruction in carcinoma.

(c) The length and contour of the lesion — characteristically long, with ill-defined extremities in diverticulitis; and short, with well-defined overhanging edges in carcinoma.

(4) Difficulty in diagnosis is increased markedly when a complete obstruction prevents adequate outlining of the whole lesion by barium.

(5) The concomitant occurrence of the two lesions is rare, and it is improbable that any direct etiological relationship exists between the two.

(6) The frequency (in this series) of diverticulitis in the distal colon almost parallels that of carcinoma.

(7) In any suspected lesion in the region of the sigmoid, thorough roentgenoscopic study and associated detail films are imperative for correct diagnosis.

CONCLUSIONS

(1) En l'absence d'une biopsie positive par sigmoidoscopie, le diagnostic différentiel entre diverculite et cancer des colons descendant et sigmoide relève surtout du roentgen-diagnostic, l'anamnèse et les signes physiques ne présentant pas de caractères nets.

(2) Une douleur localisée et une masse palpable ne présentent guère d'intérêt du point de vue diagnostic, mais nous croyons les avoir rencontrées plus fréquemment associées à la diverculite, de même que les réactions spasmodiques de voisinage.

(3) Les trois principaux éléments du diagnostic radiologique différentiel sont:

(a) Présence ou absence de diverticules. Ceux-ci peuvent exister et ne pas être démontrables; mais leur absence constitue une forte présomption de cancer.

(b) L'état de la muqueuse (indemne dans les diverticulites, remaniée dans le cancer).

(c) Le volume et l'extension des lésions (longues, étendues, sans bords nets dans les diverticulites; courtes et de limites nettes dans le cancer).

(4) Le diagnostic différentiel est particulièrement difficile lorsqu'une obstruction complète empêche le barium de mouler les contours de la lésion.

(5) La simultanéité des deux lésions est rare et il n'existe probablement aucune interrelation de l'une sur l'autre.

(6) La fréquence dans notre série de cas de la diverticulite sur le colon distal est à peu près la même que celle du cancer.

(7) Dans toute lésion suspecte du sigmoide, une exploration radiologique complète et minutieuse s'impose.

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X-RAY PROTECTION*

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The starting point in any discussion of x-ray protection must of necessity be agreement on or, at least, acceptance of a 'tolerance dose', i.e., an exposure which it is considered persons working with x-ray equipment may receive safely day after day for an indefinite period. There is as yet no general agreement on a proper value of tolerance dose; some of the values in current use are listed below.

International standard (1937)	= 1.0 r per week
U.S. standard (1946)	= 0.1 r per day
Canadian standard (N.R.C. — 1948)	= 0.05 r per day
Revised U.S. standard (N.B.S. — 1949)	= 0.3 r per week

From the standpoint of injury to the exposed individual, there is a tolerance dose or, better, a tolerance dose rate in the sense of a dose rate below which no injurious effects are produced, i.e., below this level natural processes can repair completely the damage sustained. For genetic injury, however, there is no tolerance dose in the sense defined above; the probability of genetic injury is directly proportional to the total exposure received with zero threshold and is independent of the exposure rate. As Henshaw points out, from the genetic standpoint we must think of tolerance dose not as a non-injurious dose but, rather, as a dose which limits the risk of genetic injury to a tolerable level. Establishment of a proper value of tolerance dose depends, therefore, on determination of the threshold for injury to the exposed individual and decision as to what constitutes a tolerable risk of genetic injury. Whatever tolerance dose is accepted, it is clear because of the genetic factor that the ideal is zero exposure, i.e., the tolerance dose should be treated as the upper limit of permissible exposure but under all circumstances all reasonable and practical precautions should be taken to keep the actual exposure to the lowest possible level.

In this paper an exposure of 0.3 r per week is taken as the tolerance dose. Equivalent statements of this tolerance dose rate are as follows.

Weekly tolerance	= 0.300 roentgens or 300 milliroentgens
Daily tolerance (5 day week)	= 0.060 r. or 60 mr.
Hourly tolerance (8 hour day)	= 0.0075 r. or 7.5 mr.

*Condensation of a paper read before the British Columbia Division, Canadian Association of Radiologists, on April 28, 1950.

A radiologist exposed at this rate for 15 years accumulates a total dose of approximately 220 roentgens. It is interesting to note that this exposure is comparable with the maximum exposure received by fertile survivors of an atomic bomb explosion (estimated at 300 to 350 r), i.e., a radiologist exposed at tolerance level for a 15-year period suffers a risk of genetic mutation of the same order as that suffered by atomic bomb survivors.

General Considerations

The possible sources of x-ray exposure of patients or operating personal are (a) the useful beam (that part of the radiation from the target which is directed on to the patient for radiological purposes), (b) direct radiation (radiation from the target other than the useful beam, i.e., radiation which is transmitted through the tube shield), and (c) radiation scattered from matter in the path of the useful beam. The patient is of necessity exposed to all three of these sources of radiation and the radiologist and technician may be. The permissible exposure of the patient can be determined only in relation to the value of the proposed radiological procedure. The exposure of operating personnel depends on (a) the design of the x-ray equipment (including built-in shielding), (b) protective materials used external to the x-ray equipment, and (c) techniques employed and procedures followed.

The useful beam and the stray radiations are of a completely different order of magnitude, the former being of the order of 1000 times greater than the latter. The operator must never be exposed to the useful beam, even with lead apron and gloves. With present day equipment the radiation scattered from the patient is, in general, considerably more intense than the direct radiation emerging from the tube head, i.e., while 'ray-proof' tube heads are not ray-proof in the strict sense, further shielding would increase the weight of the tube head without reducing the total stray radiation appreciably. This general statement must not, however, be taken as meaning that all ray-proof tube heads are adequately shielded.

Exposure in Radiography

Several investigators[2,3,4] have measured the exposures at different positions in a radiographic room under typical operating conditions. The exposures shown in figure 1 are averages from the various sources and may be taken as typical.

They are given in roentgens or milliroentgens per 100 milliampere-seconds of operation. While the exposures shown will vary considerably with operating conditions, it is evident that a technician who habitually stands close to the patient without protection while films are exposed is almost certain to exceed the tolerance dose. At a distance of 6 feet or greater from the patient the probability of exceeding tolerance is small but this should not be taken as justification for staying in the room while films are exposed. In keeping with the general principle that no

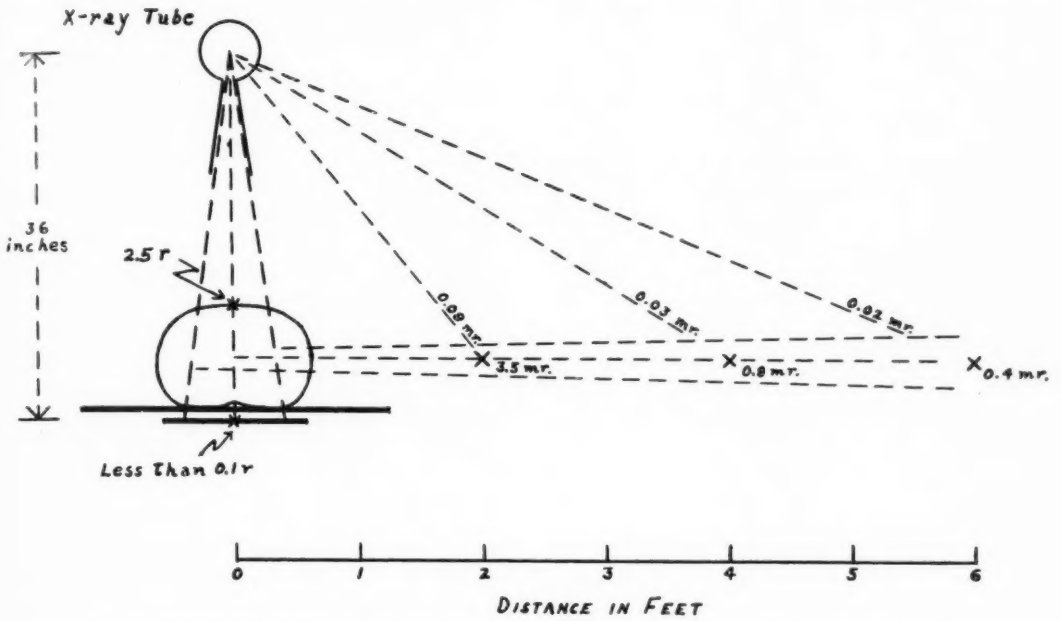

Fig. 1: Typical exposures in radiography in roentgens or milliroentgens per 100 ma.-sec. of operation.

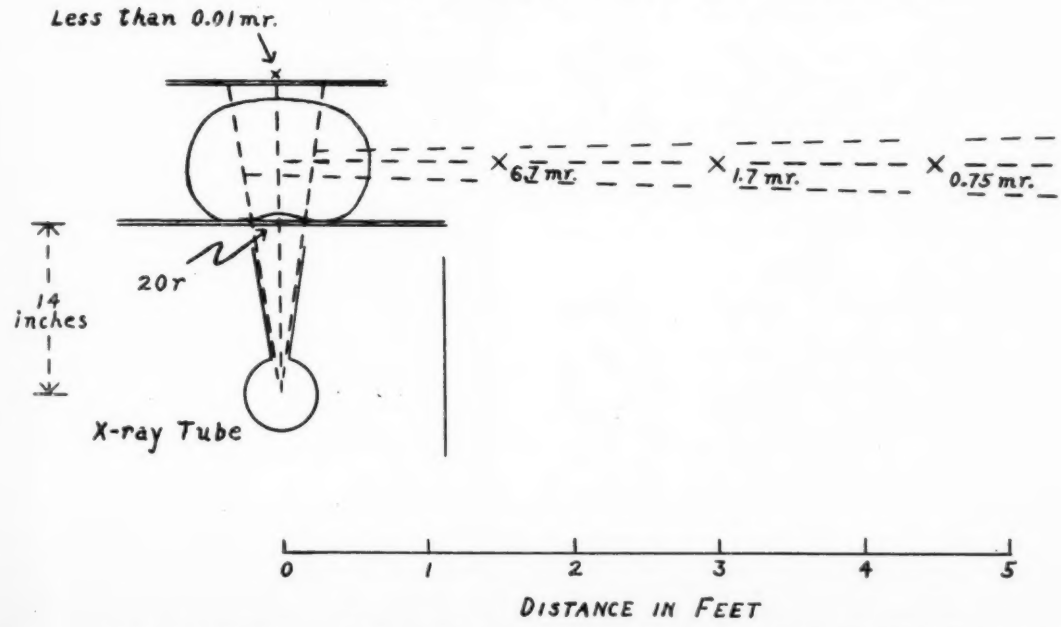

Fig. 2: Typical exposures in fluoroscopy in roentgens or milliroentgens per minute of operation.

exposure should be received which can reasonably be avoided, the operator should be out of the room (i.e., in a lead-shielded booth) when films are taken and on occasion when it is essential to remain in the room should wear a lead rubber apron.

Exposure of technicians working with portable radiographic equipment is considerably higher than with stationary units, in part, at least, due to lighter shielding of the tube head. It has been recommended[5] that technicians working without lead rubber aprons should be limited to 15000 ma-sec. of operation per week: if lead rubber apron is used this figure may be increased by a factor of 5 or more. In order to keep exposure to a minimum, a lead rubber apron should, of course, be worn if at all practical even though weekly operation is less than 15000 ma-sec.

With photofluorographic equipment, operators' exposures tend to be high because of the large number of films per day and because of the much greater quantity of radiation per film than in ordinary chest radiography. For these reasons it is particularly important that operators be protected by lead screens while films are taken; it is advisable that the exposure switches be wired and placed so that the tube can be energized only when all operators are fully protected. Without lead protection, tolerance dose is likely to be exceeded even at 12 or 15 feet from tube and patient.[6]

Exposure in Fluoroscopy

Figure 2 shows exposures in different positions around a typical fluoroscopic unit.* While the diagram shows a horizontal unit the figures are equally applicable to vertical or tilt table units. With the usual lead glass backing of the fluorescent screen, that part of the radiologist's body behind the screen is adequately protected. On the other hand, the radiologist who persistently places his hand in front of the screen is likely to suffer overexposure of that member even though lead rubber gloves are worn. To protect from radiation scattered from the patient past the edges of the screen, it is essential that the radiologist wear lead rubber apron and gloves at all times. This is particularly important for horizontal fluoroscopy but should be the rule for all fluoroscopy. Exposure of the radiologist's arms and feet depends on the design of the equipment and the radiologist's technique but is high enough to merit consideration and measurement.

*In some units a relatively intense beam of scattered radiation emerges from the slot through which the Bucky diaphragm fits. This has been omitted from the diagram since it is scarcely typical but is an important source of exposure when present.

As in the case of radiography, the technician who habitually stands close to the patient without protection while the tube is energized is likely to exceed tolerance dose. To keep the technician's exposure to a minimum, he should be in the room during fluoroscopy only when essential and then should be protected by lead rubber apron and should remain at the maximum practical distance from the patient.

Exposure in Therapy

The following are measurements made on one particular deep therapy machine.

Operating conditions: 220 KV., 20 ma., F.S.D. = 50 cm., area of field = 200 sq. cm., H.V.L. = 1.6 mm. Cu

Skin dose rate = 43 r per minute

Exposure at 1 meter from tube head due to direct radiation = 0.6 mr. per min.

Exposure at 1 meter from the patient due to scattered radiation = 30 mr. per min.

The exposure due to direct radiation will depend on the tube head and will differ from unit to unit but the figure shown for scattered radiation should be typical for 200 to 250 KV. therapy. It is evident that the technician must never be in the room while treatment is in progress since the daily tolerance dose will be received in a few minutes. Further, with the usual tube shielding it is not permissible to position patients with the tube energized. If for any reason the latter procedure is necessary particular care must be taken in shielding the tube to reduce the exposure to direct radiation below the tolerance level. In deep therapy no dependence should be placed on a lead rubber apron since it reduces exposure by a small factor perhaps, 30 to 50%.

Structural Shielding

In general, lead or other protective material must be used on the walls of the examination or treatment room to reduce the exposure outside the room below tolerance level. The actual quantity of protective material required depends on the kind of material used, the size of the room, and the maximum ratings of the unit. National Bureau of Standards Handbook 41, 'Medical X-Ray Protection up to Two Million Volts', gives rather complete and reliable data from which the requirements for adequate lead shielding may be determined. The following table shows the shielding required for typical diagnostic and therapy units to protect from the useful beam. (In the case of therapy units, it has been assumed in the table that the wall to be shielded is at a distance of 6 feet from the tube.) The table also shows the minimum safe distance for protection from the useful beam if no shielding is used. If the nearest occupied building is at less than this minimum distance shielding of outside walls is necessary.

Equipment	*Kilovoltage*	*Current*	*Shielding*	*Minimum safe distance without shielding*
Fluoroscopic	100 KV.	5 ma.	0.5 mm. of Pb	
Radiographic	100 KV.		1.5 mm. of Pb	115 feet
Superficial therapy	100 KV.	8 ma.	2.6 mm. of Pb	310 feet
Deep therapy	200 KV.	20 ma.	5.8 mm. of Pb	460 feet
Deep therapy	250 KV.	15 ma.	9.8 mm. of Pb	460 feet
Deep therapy	400 KV.	5 ma.	21 mm. of Pb	360 feet
Supervoltage	1 MV.	3 ma.	132 mm. Pb or 32 in. concrete	730 feet

It is worth noting that at low voltages concrete is a relatively poor shielding material, the thickness for adequate protection being about 75 times that of the corresponding lead shield[7]. At high voltages, however, it is an economical form of shielding, the thickness required being only 7 times that of lead.

Measurement of Exposure of Operators

It cannot be emphasized too strongly that, no matter how well shielded the equipment and no matter how adequate the structural shielding is believed to be, the actual exposure of operating personnel should be measured. Two alternative or, better, complementary methods may be employed, namely, radiation survey and personal monitoring.

In a radiation survey the actual exposure in a given location is measured in milliroentgens per hour with a survey meter. (Ionization chamber instruments are preferable to Geiger counter instruments for a quantitative survey.) Measurements should be made under the most unfavorable conditions, i.e., under conditions of highest possible exposure. Areas in which a radiation survey indicates exposures above the tolerance dose rate must, of course, be given further protection.

Even though a radiation survey of the x-ray installation is made, measurement routinely or at frequent intervals of the actual exposure received by radiologists and technicians (i.e., personnel monitoring) is always desirable since regions of high exposure may be overlooked in a survey and since careless procedures can result in overexposure no matter how effective the shielding. The measurements may be made either with pocket ionization chambers or with dental films. The former are more accurate and, perhaps, more convenient but the first cost of the equipment is greater. Dental films provide a cheap method of monitoring and, if the exposed films are compared with films which have been exposed to measured quantities of radiation, reasonably accurate measurements of exposure may be obtained. In general, it is more economical and more satisfactory to obtain films from one of the available government or commercial film services than it is to attempt to process and calibrate one's own films. With either ionization chambers or dental films calibration should be made with the same quality of radiation as that to which the monitored personnel are exposed.

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SURGICAL EMPHYSEMA FOLLOWING DOUBLE CONTRAST ENEMA
A CASE REPORT

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Perforation of the rectum occurring in the course of a double contrast barium enema is infrequent enough to record. The following case illustrates that the possibility should be kept in mind and suggests ways of avoiding or minimizing a similar mishap.

REPORT OF CASE

Clinical Observations

Mr. B. J. F., age 63, was admitted December 17, 1949, for the investigation of jaundice and abdominal pain. Two months prior to admission, a transurethral prostatectomy was done for carcinoma. One week after operation he suffered a sharp pain in his right upper quadrant, which persisted up to the time of admission as a dull constant ache. A lamellated calculus believed to be biliary was noted on a roentgenogram taken at that time. Six days prior to admission it was noted that Mr. F. was becoming jaundiced.

A barium enema was done on January 3rd, 1950. Barium passed freely into the colon as far as the caecum. A questionable area of narrowing was noted in the proximal transverse colon, and because of this it was thought that a double contrast examination would be of some help. The remainder of the colon appeared normal. After spot films and a large film of the abdomen had been taken, the patient was allowed to evacuate the barium. A post-evacuation roentgenogram was taken and the metal tip of the colon air insufflator was inserted into the rectum by an experienced orderly. Under fluoroscopy, insufflation of air was begun slowly. When about 200 c.c. of air had been introduced, an interesting phenomenon was apparent. No air was seen filling the rectum or sigmoid, and it appeared as if the peritoneum was stripped off the posterior abdominal wall by air. The psoas muscles, both kidneys, and spleen were clearly outlined by air. The insufflation of air was stopped immediately. At this time the roentgenogram seen in Fig. 1 was taken. The patient suffered no pain or shock, but the following afternoon showed elevation of temperature to 100.8° F.

On the following day, roentgenograms of the abdomen revealed air in the retroperitoneal space in the pelvis and posterior abdominal wall, as on the previous day but more diffusely spread. An upright film showed no free air under the diaphram. A chest roentgenogram (Fig. 2) showed air bilaterally in the subcutaneous tissues of the chest wall. Some air was also seen in the pleuropericardial space, along the left margin of the heart. On palpation of the abdomen and subcutaneous tissues of the chest, emphysematous crepitations were noted. A digital and proctoscopic examination of the rectum showed no abnormality.

Fig. 1: Roentgenogram taken after the air insufflation (Jan. 3, 1950). Note the retroperitoneal air in the pelvis, and outlining the psoas muscles, kidneys and spleen. A lamellated biliary calculus is seen.

One week later all the air in the chest wall and pleuropericardial space as well as most of the retroperitoneal air was absorbed.

Two weeks later all the retroperitoneal air was absorbed. The patient had no symptoms referable to the diffuse emphysema.

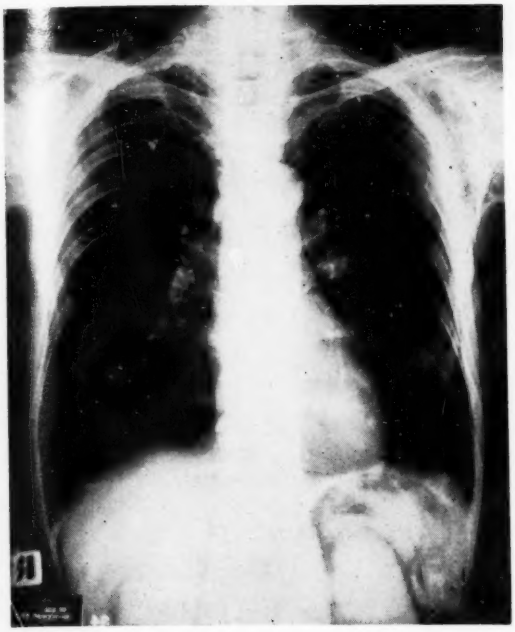

Fig. 2: Roentgenogram taken the day after the air insufflation (Jan. 4, 1950). Emphysema of the subcutaneous tissues of the chest wall is noted bilaterally. A pleural line is seen parallel to the left heart margin outlining pleuropericardial air. The spleen is well outlined.

Discussion

Only one case similar to this has been reported (Brown and Fine). (1) Air insufflation was not done under fluoroscopic control, but a squeaking noise was heard during insufflation and the patient felt a fullness of the abdomen. In addition to retroperitoneal air, there was marked interstitial emphysema of the neck and anterior mediastinum.

Pratt and Jackman (2) in an excellent review of the literature on perforation of the rectal wall by enema tips, emphasized that perforation in the course of an enema was a surgical emergency with a 40 percent mortality. Twenty cases in the literature were summarized but Brown and Fine's case was not mentioned.

Rayner (3) believed that the most essential factor in the production of perforation was the use of a hard nozzle. The injury may be caused by first sucking the rectal mucous membrane into the opening or openings of the tube. Injury to the relatively insensitive rectum will cause little or no pain or discomfort and hence the enema fluid may be injected into the peritoneal cavity or along the course of the fascial planes.

In considering how retroperitoneal insufflation can be avoided, it is obvious that the chance of damage to the rectal mucosa is greater when a rigid, metallic tip is used. Care in introducing the insufflator tip is essential. However, if in spite of precautions, there is a break in the rectal mucosa, it is suggested that insufflation always be done during fluoroscopy so that the direction of the air can be checked and insufflation stopped.

In this case it was difficult to explain the passage of air through an apparently intact rectal wall. Possibly a very small opening of a valve — like nature was present.

SUMMARY

Widespread surgical emphysema involving the retroperitoneal space, mediastinum and soft tissues of the thorax, occurred as a complication of a double contrast barium enema. The patient showed no reaction, and all the air was absorbed in two weeks' time.

RÉSUMÉ

Relation d'un cas d'emphysème géant de l'espace rétropéritonéal du médiastin et des tissus mous du thorax comme complication d'une insufflation colique après lavement opaque. On n'enrégistra chez le patient aucune réaction et l'emphysème se résorba complètement dans deux semaines.

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HAVE WE A RADIOGRAPHIC SIGN OF GRAVE PROGNOSIS?

A Preliminary Communication

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THE HOMOEOPATHIC HOSPITAL OF MONTREAL

Some five years ago while reviewing chest films of patients with heart disease, I noticed that the superficial tissues of the thorax in the regions of the neck, above the clavicles and in the axillae became more transparent to x-ray before these patients died. This change in the radiographic density of the skin, subcutaneous fat and the muscular tissues varied from a slight blankening of the neck, supraclavicular and auxillary regions to that where skin and subcutaneous tissues were not visible and the muscular tissue showed no detail that would enable one to distinguish the sternocleidomastoid muscle or the trapezius. From time to time I drew the clinicians' attention to the change in the radiographic density of their patients' tissues, and hazarded a guess that the prognoses were grave.

Using this change in radiographic density as a sign, we have tried to predict the prognosis in a number of cases during the past few years, and the following case illustrates one of these predictions.

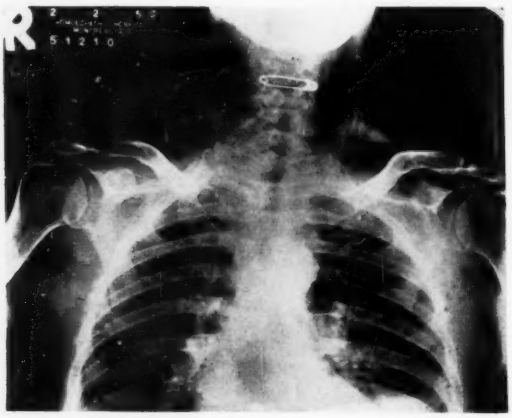

Figure 1

Typical is this film of a woman of 60 years of age, Mrs. McK., admitted to the hospital for treatment of arthritis. We had no previous films of her chest as she had been bedridden for 2½ years. On admission she had considerable oedema of both ankles. A radiograph of the chest showed evidence of passive congestion of the lungs, enlargement of the heart, and, as the superficial tissues of the thorax were unusually transparent, a grave prognosis was suggested. Thirteen days later she died. At autopsy there was evidence of rheumatic heart disease, generalized arteriosclerosis, coronary sclerosis, hypertrophy and dilatation of the heart with myocardial scarring.

The variation in the density of the superficial tissues causes one to suspect the technical factors, but when one has checked and compared these, even under such varying conditions that are presented by patients who are gravely ill, one realizes that these changes are not altogether due to radiographic technique for the density of the lungs does not change correspondingly.

The change in density of the soft tissues of the thorax could be explained on the basis of lack of water content of these tissues, and the following illustrations are offered as an example of such a change.

Figure 2A is a radiograph of a dry sponge. Figure 2B is that of the same sponge but it has been soaked in water and then the water has been squeezed out as much as one could possibly do by hand. A triangular section of this damp sponge was cut out and again soaked in water, then squeezed so that it would not drip and again placed with the main portion of the sponge. The difference in the radiographic density between the dry sponge and the same sponge with the water squeezed out of it is evident, but the greater difference is seen in the triangular section of sponge which contains almost its maximum amount of water. If, then, one tries to explain the changes in the superficial tissues of the thorax on the basis of dehydration, one might reason from the above example on the basis of analogy. However, this is not a true analogy and I believe that other factors operate, though the changes might be produced to some extent by dehydration of tissues, diminished fluid intake or malnutrition. In cardiac cases a grave circulatory failure might well be the predominating factor. If this is so, it would seem reasonable to assume that in a patient with failing circulation there comes a time when these changes occurring in the superficial tissues are not reversible but progressive, and thus we may have a radiographic sign of approaching death.

To establish this statistically would require a greater number of cases than those which fall to the lot of one radiologist, for it could be argued that the small number of patients of which one has early and late films, is not a proper sample for statistical purposes. One must, therefore, seek a wider application and test this sign

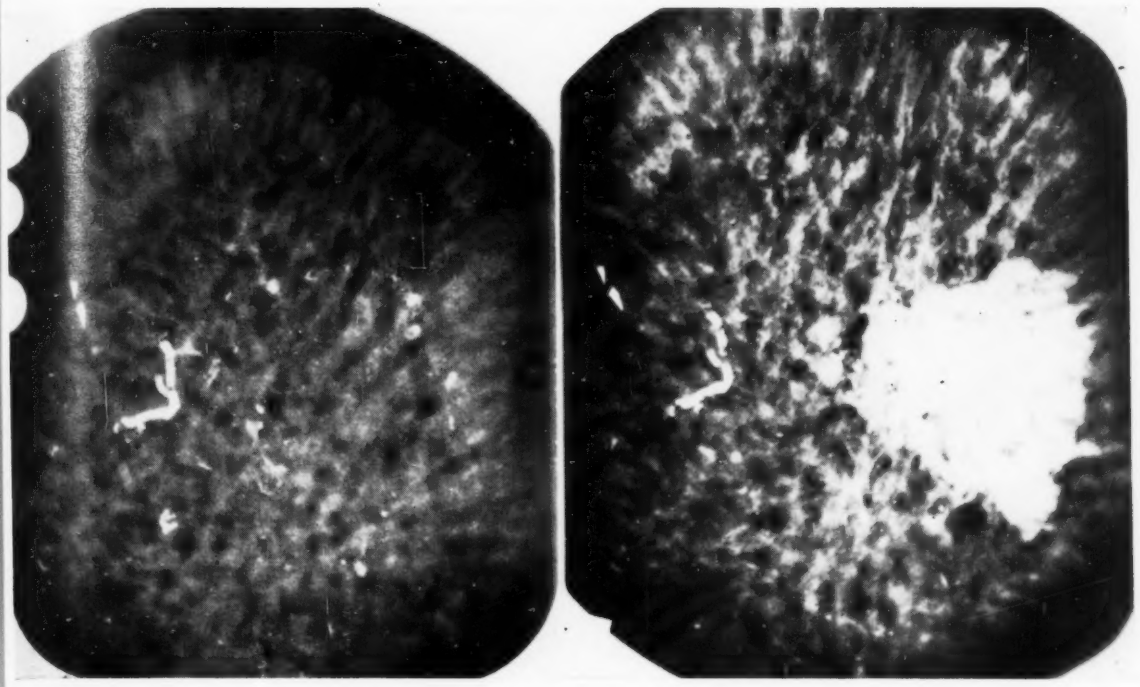

Figure 2A and 2B

by the experience of other radiologists. Such is the purpose of this communication.

As a matter of caution, one must remind onself that there is usually an exception to any established rule, and some might cite the following case as such an exception.

Mrs. McC. was gravely ill with multiple infarcts in the lung and for a long time her attending physicians despaired of her life. She showed the changes described above, but she recovered eventually and the superficial tissues of her thorax returned to normal radiographic density after a period of almost a year. It is significant, however, that at no time were her physicians concerned about cardiac failure. The films, during this period of time, were taken under varying conditions, and we have not been able to reproduce the variation in densities satisfactorily. We must recognize that the prognosis was grave for a long time, but at no time did she show evidence of cardiac failure.

SUMMARY

1. A change in the transparency of the superficial tissues of the thorax and neck, particularly the skin and subcutaneous fat, has been noted in the radiographs of the chests of cardiac patients who died some days later. The time of the appearance of this change is a variable one, but in one patient it was noted thirteen days before death. It is suggested that this may be a sign a grave prognosis, especially, in cardiac patients and may indicate approaching death.

2. An explanation is offered on the basis of the fluid content of superficial tissues and a comparison made with radiographs of a sponge containing variable amounts of water, but this does not satisfy all the conditions.

3. The cases that one radiologist can offer may not be statistically significant, and a wider application of this communication is sought in the experience of other radiologists.

RESUME

On a souvent observé sur les clichés radiographiques de la poitrine, des cardiaques et autres malades, quelques jours avant leur mort, des modifications de transparence au niveau des parties molles du cou et du thorax. Le moment de l'apparition de ces changements est variable, et peut aller jusqu'à treize jours avant le décès comme nous l'avons observé.

L'on a tenté d'expliquer ce phénomène en avançant qu'il repose sur une différence de concentration des liquides dans les parties molles, en se basant sur des comparaisons établies sur des différences d'aspects radiographiques obtenus avec une éponge imbibée de quantités variables d'eau. Cependant cette explication ne s'applique pas à tous les cas.

Les quelques cas qu'un radiologiste peut présenter n'ont peut-être pas une valeur statistique marquée et cette communication est simplement soumise afin de provoquer les commentaires et les observations des autres radiologistes.

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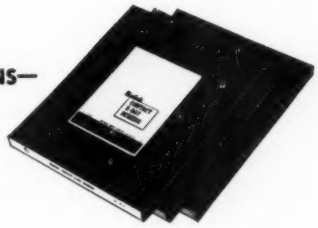

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NEW FUNDS AVAILABLE FOR RADIOLOGICAL RESEARCH*

The National Research Council announces the availability of funds for fundamentals research in the field of radiology. This has been made possible by the James Picker Foundation, established in 1947 by Mr. Picker and his family. Capital funds of the Foundation now approximate $400,000.

The announced objectives of the James Picker Foundation are "to provide funds to foster research and broaden the scope of radiology."

For the year 1950, $15,000 from income will be available for research. In allocating these funds, special consideration will be given to fundamental work in radiology and its applied fields. The Foundation has specifically requested that none of its funds be used to subsidize the development of radiological equipment.

The National Research Council has been designated as the scientific advisory body of the Foundation. It is expected that applications will be considered by the Council's Committee on Radiology under the Chairmanship of Dr. Eugene P. Pendergrass. Final determination of the awards will be made by the Directors of the Foundation upon the recommendation of the National Research Council.

The Directors of the James Picker Foundation are: Harold E. Stassen (Chairman) — President, University of Pennsylvania; General George Doriot—Professor, Harvard University; Ivan Dresser—Vice-President, General Motors Overseas Corporation; Ross Golden, M.D.— Professor of Radiology, College of Physicians and Surgeons, Columbia University.

Applications for fellowships in the field of radiological research, with stipends of the order of $3,000 to $5,000, depending upon the qualifications and special circumstances of the applicant, will also be entertained.

Applications for research grants and fellowships available during the year beginning January 1, 1951, will be entertained until September 15, 1950, and are ***NOT*** limited to citizens of or laboratories in the United States.

Enquiries should be addressed to: Secretary, Division of Medical Sciences, National Research Council, 2101 Constitution Avenue, Washington 25, D.C.

* From The American Journal of Roentgenology and Radium Therapy, April 1950, Page 59.

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The Annual Meeting of the Canadian Society of Radiological Technicians is scheduled for September 6th, 7th, 8th and 9th at the Georgia Hotel, Vancouver, B.C. The Canadian Association of Radiologists extends best wishes for a successful meeting.

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EDITORIAL

"Come, come, and sit you down; you shall not budge;

"You go not till I set you up a glass

"Where you may see the inmost part of you".

HAMLET, Act III, Scene 4.

Within the past few weeks a group of young radiologists have been examined as to their knowledge in this field of medical science and art. But in how many instances have the more senior radiologists, and the body of radiology generally, looked upon them as the "glass" within which we may see the inmost part of ourselves and our specialty ? For what role have we tried and succeeded, or failed, to educate them ? Have we kept faith with them, their future patients and professional colleagues, or, like Hamlet's mother, violated the trust and sloughed-off our responsibility for some selfish end ?

The inception of radiology was the product of a great and humble scientist, followed shortly by two similar, self-effacing investigators. Once these three had shown the scientific world the basic tools, the applications in the fields of medicine, scientific investigation, industry and, lately warfare, mushroomed. Today, it is far more evident than when the late G. W. C. Kaye wrote (1928) that "the diversity of the applications of the roentgen rays has indeed become such that one scarcely envies the task of future students of the subject" He certainly included radium radiation in his thought, and must have anticipated in some measure the modern alchemy of atomic fission.

The education of the clinical radiologist of today and tomorrow must prepare him to consult with his colleagues on virtually any detail of the anatomy of the human, or some other favourite animal, its normal physiologic processes or the vagaries of the pathologic physiology of disease; to examine their patients objectively; and then, weighing his observations with other scientific evidence and the subjective information available, to arrive at a responsible differential diagnosis and opinion. Or, if a question of treatment should arise, he must be able to advise as to the suitability or non-usefulness of roentgen therapy, radium irradiation or perhaps radio-active isotope administration; too often as well, to carry the entire responsibility for the clinical management, after-care and follow-up of the cancer patient, especially. In each and every one of these phases he is expected to be as knowledgeable as his individual professional colleagues are in their respective special spheres, and to be a master of technique.

The trend in some countries towards the early complete divorcement of diagnostic and therapeutic radiology is unfortunate, and for a high percentage of the communities of Canada would deprive the sick of much-needed counsel in regard to therapy, particularly.

The rudiments of both diagnostic and therapeutic radiology can be relatively quickly absorbed and organized by a physician who has been well-grounded in his undergraduate medical curriculum, then developed and matured during a carefully supervised rotation interneship, followed by at least a year of resident instruction and study of internal medicine in a hospital whose attending staff will teach the resident staff. Further clinical training in surgery, pathology and the other special fields would strengthen his position, if time and means afford.

But the full development of the embryo radiologist to maturity in so broad a field can be accomplished only if it includes adequate instruction in techniques and the cognate basic sciences, and the constant nurture of each graduate student by his senior instructors during the observation of sufficiently diversified and quantitative clinical material for him to attain judgment regarding the significance of altered structure or function and the biologic response to irradiation. There are few *labels* to be found on roentgenograms, and no two people react exactly alike under radiation therapy. A descriptive vocabulary and semi-intuitive diagnostic pronouncements are not the mark of a radiologist nor the substitute for knowledge of fundamentals, and the analytical reasoning power of a consultant.

This places a grave responsibility on those who undertake to staff the training centres and to teach the oncoming generations of radiologists; and poses problems as to the economic maintenance of the graduate student during the five to six years of his post-graduate course.

Canadian radiology can, if it will look into the "glass" frankly, so guide its further progress as to be proud of having met the challenge.

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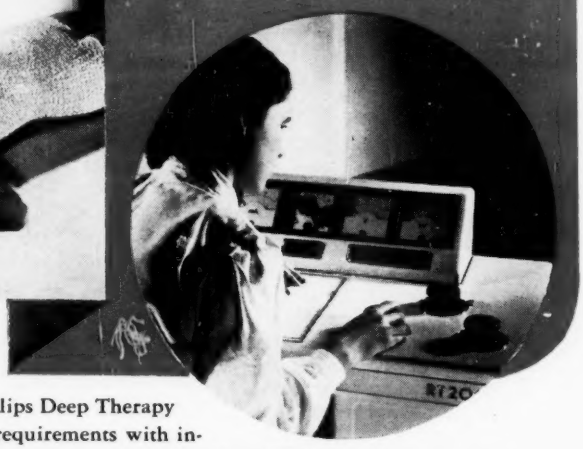

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